Language Functions in Preterm-Born Children: A Systematic Review and Meta-analysis

BACKGROUND AND OBJECTIVE: Preterm-born children (<37 weeks’ gestation) have higher rates of language function problems compared with term-born children. It is unknown whether these problems decrease, deteriorate, or remain stable over time. The goal of this research was to determine the developmental course of language functions in preterm-born children from 3 to 12 years of age.

METHODS: Computerized databases Embase, PubMed, Web of Knowledge, and PsycInfo were searched for studies published between January 1995 and March 2011 reporting language functions in preterm-born children. Outcome measures were simple language function assessed by using the Peabody Picture Vocabulary Test and complex language function assessed by using the Clinical Evaluation of Language Fundamentals. Pooled effect sizes (in terms of Cohen’s d) and 95% confidence intervals (CI) for simple and complex language functions were calculated by using random-effects models. Meta-regression was conducted with mean difference of effect size as the outcome variable and assessment age as the explanatory variable.

RESULTS: Preterm-born children scored significantly lower compared with term-born children on simple (d = −0.45 [95% CI: −0.59 to −0.30]; P < .001) and on complex (d = −0.62 [95% CI: −0.82 to −0.43]; P < .001) language function tests, even in the absence of major disabilities and independent of social economic status. For complex language function (but not for simple language function), group differences between preterm- and term-born children increased significantly from 3 to 12 years of age (slope = −0.05; P = .03).

CONCLUSIONS: While growing up, preterm-born children have increasing difficulties with complex language function. Pediatrics 2012;129:745–754
According to a recent publication of the World Health Organization, worldwide ~13 million babies are born preterm annually. Preterm birth, defined as born before 37 weeks of gestation, constitutes a major challenge in perinatal health care. Children born prematurely are at greater risk for major disabilities such as cerebral palsy, mental retardation, and severe visual and hearing loss than term-born children. These major disabilities are relatively rare; however, more subtle developmental problems have often been described in preterm-born children. Meta-analyses highlighted substantial impairment in multiple developmental domains in preterm-born children throughout childhood, such as cognitive and motor development, behavior, and academic achievement. Preterm birth coincides with higher rates of problems with language function compared with term-born children. Language function can be divided into 5 components: semantics (rules governing the meaning of words and sentences), phonology (rules governing speech sounds to signal meaning), morphology (rules governing change in word meaning related to change in word form), syntax (rules governing how words can be combined to form phrases, clauses, and sentences), and pragmatics (rules governing the use of language in a social context). In brain and linguistic research, language functions are often divided into simple and complex to discriminate between more basic and more complex verbal processes. Simple language function comprises, for instance, vocabulary and the acquisition of short main clauses. Complex language function, characterized by the integration across multiple language components, comprises the meaning of complex concepts, including verbs or relational terms, and sentences consisting of main and subordinate clauses.

Despite the large amount of research conducted on language function in preterm-born children, it is still unknown to what extent problems in language function at an early age decrease, deteriorate, or remain stable over time. Because language function is essential in all kinds of social and academic life, insight in the developmental course of language functions in preterm-born children is of great value. Timely detection and appropriate intervention of language problems in this vulnerable population may prevent emotional, social, and learning deficits, and may improve long-term outcomes, reducing the need for special education.

The aim of this study was to investigate the developmental course of language functions in preterm-born children compared with term-born children throughout childhood by performing a meta-analysis. A meta-analysis on the developmental course of language functions is useful because of the larger sample size and the larger number of age points compared with the few longitudinal single studies addressing this topic.

**METHODS**

**Selection of Studies**

In undertaking this study, the guidelines made by the Meta-analysis of Observational Studies in Epidemiology group were followed. First, the computerized databases Embase, PubMed, Web of Knowledge, and PsycInfo were searched for articles by combining the search terms premature*, preterm, low birth weight, gestational age AND speech, language, communicat*, interact*, verbal, and psycholinguistics. Second, reference lists of published articles were hand-searched to identify additional relevant studies. Third, experts on preterm outcome (pediatricians and neuropsychologists) were contacted to ascertain additional studies. The following inclusion criteria were used: (1) the study included children born preterm (gestational age <37 weeks); (2) the study was published between January 1995 and March 2011 (1995 was chosen because of the significant improvements in neonatal care that had resulted in a much better condition of preterm-born children from that time on [eg, the combination of antenatal steroids to improve lung matura-
tion before delivery and improved obstetric management]); (3) the study was published in an English-language peer-reviewed journal; (4) the study reported mean or median language outcomes collected with a reliable and validated language test; (5) a case-control design was used to minimize stratification bias; (6) the language test was used in at least 5 studies included in this meta-analysis to ensure stability of the results; and (7) the study was of sufficient quality, according to the Newcastle-Ottawa Scale. Studies were excluded if they did not meet all of these inclusion criteria. If the same population of preterm-born children was the subject of several studies, only the study with the largest sample size was included.

**Quality Assessment**

Quality assessment was undertaken independently by 2 authors (Van Noort-van der Spek and Franken) by using the Newcastle-Ottawa Scale. This scale assesses the quality of case-control studies in terms of selection of children (4 criteria), comparability of study groups (1 criterion), and outcome assessment (3 criteria). The total rating score ranges from 1 to 9, with 9 being the most favorable. Disagreements between authors with regard to data extraction and quality assessment were resolved by discussion.

**Outcome Measures**

On the basis of the inclusion criteria, studies using the Peabody Picture Vocabulary Test (PPVT, including the revised version [PPVT-R]), the third
version [PPVT-III]. The British version, the PPVT (PPVT-R, PPVT-III, PPVT-IV), the third version [CELF-3] could be included.

The included language tests are well established, generally accepted, and have good reliability and validity. The PPVT is a picture-based measure of receptive vocabulary, a simple language function within the domain of semantics. All versions of the PPVT have a mean ± SD of 100 ± 15.

The CELF is a comprehensive test of complex receptive and expressive language function, including subtests for semantics, grammar, syntax, and working memory for language. All versions of the CELF yield composite scores for receptive language, expressive language, and total language, with a mean ± SD of 100 ± 15.

Mean gestational age (GA), birth weight (BW), major disabilities, year of birth, gender, assessment age, socioeconomic status (SES), and mean full-scale IQ (FS-IQ) were obtained from each study.

**Statistical Analyses**

Statistical analyses were performed by using Stata version 11 (Stata Corp, College Station, TX). All statistical testing was 2-sided, and \( P < .05 \) was considered significant.

Random-effects models instead of fixed-effects models were used, providing a more conservative estimate of variance in sample characteristics between studies. A standardized difference between the mean language scores of cases (preterm-born children) and controls (term-born children) was weighted according to the sample size for each study. To meet the assumption of independence of effect size, 1 point estimate of effect from each study was included. If studies reported results for subgroups of preterm-born children or controls, a weighted group mean and weighted SD were calculated by multiplying each subgroup mean and SD, respectively, by its sample size, adding the subtotals, and dividing the obtained sum by the total sample size. In case of a longitudinal study, the first assessment was used to minimize the risk of a learning effect by second testing and to optimize the age range. Pooled effect sizes were calculated by using the standardized difference of means and the corresponding weight for each study. Results are reported as Cohen’s \( d \) and 95% confidence intervals (CIs). Cohen’s guidelines were used to classify the magnitude of effect sizes: \( d = 0.2 \) represents a small effect, \( d = 0.5 \) a medium effect, and \( d = 0.8 \) a large effect. Cochran’s Q statistic and the \( I^2 \) index were conducted to assess homogeneity of effect size across studies. Statistically significant heterogeneity was considered at \( P < .05 \) and \( I^2 > 50 \).

Galbraith plots were constructed to identify outliers in analyses with significant heterogeneity. Meta-regression and subgroup analyses were performed to explore potential sources of statistical heterogeneity between studies, including GA, BW, major disabilities, year of birth, gender, FS-IQ, and SES. FS-IQ is identified as a possible cause of heterogeneity because deficits in language function may be part of general cognitive difficulties, or may represent specific language impairments.

The possibility of publication bias was assessed by using the Egger test and visual inspection of a funnel plot. We also performed Rosenthal’s fail-safe \( N \) (FSN), which measures the number of additional “negative” studies (studies in which the effect was zero) that would be needed to increase the \( P \) value for the meta-analysis to \( > .05 \). A FSN is considered robust if the estimate of unpublished studies is \( > 5 \) times the number of studies published. In addition, the correlation between sample size and effect size was investigated by using the Pearson correlation coefficients. Finally, meta-regression according to assessment age was conducted, with mean difference of effect size as the outcome variable and age at assessment as the explanatory variable.

**RESULTS**

The literature search yielded 2214 articles. After review of the abstracts, 186 articles were identified as potentially eligible for inclusion, and the full-text articles were retrieved for review. Results of the publication search and selection are presented in Fig 1. Finally, 17 studies could be included in which outcomes of language function were measured with the PPVT (PPVT-R, PPVT-III, BPVS, and BPVS-II) and the CELF (CELF-P and CELF-3). The characteristics of these studies are presented in Table 1. The meta-analytic sample comprised a total of 1529 preterm-born children and 945 term-born born children.

**Simple Language Function**

Simple language function, in terms of receptive vocabulary, was assessed in 13 studies with the PPVT. Random-effects meta-analysis revealed that preterm-born children had significantly lower receptive vocabulary scores compared with term-born children, as indicated by the combined effect size of \( d = −0.45 \) (95% CI: −0.59 to −0.30; \( P < .001 \)) (Fig 2). Significantly lower receptive vocabulary scores in preterm-born children compared with term-born children were found in 8 of the 13 studies. No statistically significant heterogeneity between the studies was found (\( Q = 19.35, P = .08 \); \( I^2 = 38.0 \)). A funnel plot and Egger test (\( P = .92 \) showed no underlying publication bias. The FSN was 304 for receptive vocabulary, and the correlation with sample size was not significant (\( r = 0.15, P = .63 \)).
Meta-regression according to assessment age did not reveal a significant increasing or decreasing difference between preterm- and term-born children from 3 to 12 years of age regarding simple language function in terms of receptive vocabulary (intercept = –0.631, slope = 0.03, $P = .35$) (Fig 3).

Complex Language Function

Complex language function, in terms of total language, was assessed in 6 studies with the CELF.24,25,37,39,40,41 Receptive and expressive language was assessed with the CELF in 5 studies.25,38–41 Preterm-born children had significantly lower total language, receptive, and expressive language scores compared with term-born children, as indicated by the combined effect size for total language ($d = –0.62$ [95% CI: –0.82 to –0.43]; $P < .001$) (Fig 2), receptive language ($d = –0.69$ [95% CI: –0.82 to –0.55]; $P < .001$), and expressive language ($d = –0.61$ [95% CI: –0.74 to –0.47]; $P < .001$) (Supplemental Fig 4). Significantly lower complex language function in preterm-born children compared with term-born children was found in all studies. Significant heterogeneity across the studies did exist for total language ($Q = 11.27, P < .05, I^2 = 55.6$). No significant heterogeneity was found across the studies for receptive ($Q = 2.00, P = .74, I^2 = 0$) or expressive ($Q = 3.21, P = .52, I^2 = 0$) language. A Galbraith plot to detect potential sources of heterogeneity for total language revealed that the study by Landry et al24 was an outlier. The only salient characteristic of this study was the relatively young assessment age; namely, 3 years. In a subgroup analysis without this study, strong evidence for absence of heterogeneity was found ($Q = 3.00, P = .56, I^2 = 0$) (Supplemental Fig 5). Sources of significant heterogeneity were not found by meta-regression analyses on mean GA (5 studies, $P = .49$), mean BW (5 studies, $P = .93$), gender (6 studies, $P = .44$), or effect sizes of mean FS-IQ (5 studies, $P = .12$).

Subgroup analyses were performed to assess the effect of SES and major disabilities on the estimated effect sizes of complex language function, in terms of total language. The effect of SES and major disabilities was analyzed according to subgroup analyses instead of meta-regression, due to the variety of outcome measures for SES and major disabilities used among the included studies. A subgroup analysis for years of birth could not be performed because only 3 of 6 studies included year of birth data, ranging from 1989 to 2000. A first subgroup analysis comprised 5 studies in which there was no significant difference regarding SES between the preterm-born children and their controls. One of the 6 studies was excluded because of a significant difference of SES between preterm- and term-born children. This analysis showed a combined effect size of $d = –0.66$ (95% CI: –0.90 to –0.41; $P < .001$), indicating a significant lower mean total language in preterm-born children compared with term-born children independent from SES (Supplemental Fig 6). The pooled effect size of all studies on total language ($d = –0.62$) was not different from the pooled effect size of the 5 studies without significant
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<td>Study/Year</td>
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<td>Test</td>
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<td>961 (174)</td>
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BPD, bronchopulmonary dysplasia; CA, corrected age; CNS, central nervous system; CPM, Coloured Progressive Matrices; FT, full-term; HR, high-risk; LBW, low birth weight; LR, low-risk; NA, not available; NBW, normal birth weight; PT, preterm; SB, Stanford-Binet; SB-Fe, Stanford-Binet Intelligence Scale, Fourth Edition; VLBW, very low birth weight; WASI, Wechsler Abbreviated Scale of Intelligence; WISC, Wechsler Intelligence Scale for Children (Third–Fifth Editions); WPPSI, Wechsler Preschool and Primary Scale of Intelligence.
a Defined as cerebral palsy, mental retardation, and severe visual and hearing loss.
b Measured by using the Newcastle-Ottawa Scale.
c Reported only total language scores.
d Reported only receptive and productive language scores.
differences of SES (–0.66). Therefore, the conclusion may be drawn that the effect sizes for total language were not influenced by major disabilities. A second subgroup analysis comprised 3 studies in which only preterm-born children without major disabilities were included. This analysis revealed a combined effect size of $d = –0.54$ (95% CI: $–1.01$ to $–0.07$; $P < .05$), indicating a significant lower mean total language even in preterm-born children without major disabilities compared with term-born children (Supplemental Fig 7). The pooled effect size of all studies on total language (–0.62) was slightly higher than the pooled effect size of the 3 studies with preterm-born children without major disabilities (–0.54). Therefore, the effect sizes for total language were somewhat influenced by major disabilities.

A funnel plot and Egger test results showed no publication bias for total language ($P = .08$), receptive language ($P = .64$), or expressive language ($P = .87$). The FSN was 205 for total language, 162 for receptive language, and 127 for expressive language. The correlation with sample size was not significant for total, receptive, and expressive language ($r = 0.31$, $P = .54$; $r = –0.70$, $P = .01$; and $r = –0.37$, $P = .54$, respectively).

Meta-regression according to assessment age revealed a significant increasing difference between preterm- and term-born children regarding complex language functions, in terms of total language, from 3 to 12 years of age (intercept $= –0.243$, slope $= –0.05$, $P = .03$) (Fig 3).

**DISCUSSION**

This meta-analysis revealed that preterm-born children score significantly lower compared with term-born children on simple, as well as on complex, language function tests throughout childhood, even in the absence of major disabilities and independent of SES. More important, for complex language function, group differences between both preterm- and term-born children significantly increased from 3 to 12 years of age. For simple language function, no significant increase or decrease between preterm- and term-born
children from 3 to 12 years of age was found. We compared our cross-sectional data on simple language function with the longitudinal data of Luu et al. and our data on complex language function with the longitudinal data of Landry et al. In the longitudinal study of Luu et al, data from preterm-born children compared with normative data did, in contrast to our study, display catch-up gains on simple language functions measured by using the revised version of the PPVT from 3 to 12 years of age. In the longitudinal study of complex language functions by Landry et al, preterm-born children from 3 to 8 years of age showed lower levels and slower rates of language development on the basis of CELF scores compared with term-born children. Both groups consisted of children from low-SES families. Our results suggest that complex language function might be a more useful index of language functioning in preterm-born children than simple language function. From a linguistic perspective, this finding could be explained by the fact that complex language function depends more on higher-order semantic and syntactic knowledge, entailing integration across language domains and having a significant working memory component. Recent findings from functional neuroimaging studies seem to support the hypothesis that early brain damage associated with preterm birth might be an important determinant of the development of complex language functions. There is growing evidence that higher-order cognition is based on cofunctioning of a set of cortical areas in a dynamic large-scale framework, highlighting the central role of cortical communication. Absence of language disabilities or amelioration of skills could be interpreted as evidence of neural and functional plasticity in response to early brain damage. Conversely, the presence of deficits in complex language functions could be an indication that the plasticity of the developing brain is limited. Recently, however, it has been demonstrated that experience and learning can bring a positive change in cortico-cortical white matter tracts in children with reading problems. To our knowledge, no studies on this issue addressing language functions exist.

An important implication of our meta-analysis is that the usual follow-up care in preterm-born children should include assessment and remediation of simple language functions as well as the more vulnerable, complex language functions, facilitating later academic achievement and social interaction. Traditionally, this is not current practice. If a preterm-born child had delayed simple language functions as a toddler and subsequently test scores are within normal limits in the preschool years, the child should still be followed up from 5 to 12 years of age for complex language function and treated in case of insufficient scores.

Future research with longitudinal designs is needed to infer the causal directions underlying the developmental course of complex language functions. Several studies have concluded that many of the language deficits in preterm-born children were more likely a result of general cognitive problems than evidence for specific language impairment. Deficits in speech sound production, however, remain present after controlling

FIGURE 3
Meta-regression assessment according to age for simple and complex language function.
for cognitive function. A few studies have focused on long-term memory development in preterm-born children, showing very poor phonological working memory that puts these children at risk for persistent language difficulties. Future research should therefore also focus on the developmental course of phonological working memory skills providing insight into the increasing difficulties with complex language functions. The assessment of phonological working memory skills and complex language functions, combined with functional neuroimaging, could address co-functioning of a set of cortical areas in a dynamic, large-scale framework.

To our knowledge, this is the first meta-analysis to evaluate the developmental course of language functions comparing preterm- and term-born children throughout childhood. A meta-analysis on this topic is of importance to gain a better understanding of the underlying mechanisms contributing to long-term learning and behavior problems reported in preterm-born individuals.

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REFERENCES

3. Bhutta AT, Cleves MA, Casey PH, Cradock-Watson P, Holt, PhD (Department of Biostatistics, Erasmus Medical University Centre–Daniel den Hoed) for statistical advice, and G.K. Smith-Venderbos, MSc (Department of Pediatric Neurology, Erasmus Medical University Centre Rotterdam–Sophia Children’s Hospital) for reviewing the English language of the manuscript.

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38. Lee ES, Yeatman JD, Luna B, Feldman HM. Specific language and reading skills in school-aged children and adolescents are associated with prematurity after controlling for IQ. Neuropsychologia. 2011;49(5):906–913
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